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MINING AND CRUSHING METHODS AND COSTS AT THE MONOCACY QUARRY OF THE JOHN T. DYER QUARRY CO. MONOCACY, PA.

BY

JOSEPH A. CONWAY

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MINING AND CRUSHING METHODS AND COSTS AT THE MONOCACY QUARRY OF THE JOHN T. DYER QUARRY CO. MONOCACY, PA.[1]

By Joseph A. Conway[2]

INTRODUCTION

This paper is one of a series dealing with the mining and crushing methods and costs of the nonmetallic industries, prepared under the sponsorship of and in cooperation with the U. S. Bureau of Mines.

The quarrying methods described in this paper are those used at the Monocacy trap rock quarry which annually produces from 450,000 to 500,000 tons of crushed stone. This property is located 3 miles east of Birdsboro at Monacacy, Pa., and is one of the three quarries operated by the John T. Dyer Quarry Co. Throughout the paper an effort is made to explain the various methods used and the cost of operation.

ACKNOWLEDGMENT

In the preparation of this paper the author received the invaluable assistance of many of his coworkers. Especial acknowledgment is made of the help so willingly extended by F. T. Gucker, president of the company, through whom the writing of this paper was made possible, William A. Kelly, superintendent of the quarry, and Henry A. Rowan, 3rd, safety engineer, who gave much of their time and advice. W. B. Prichett and Thomas McPoyle, engineers furnished the drawings.

The author also expresses his gratitude to Prof. F. E. Williams, of the University of Pennsylvania, for the information regarding the geology of the quarry, and to John C. Koster, of the E. I. Du Pont DeNemours Co., from whose article on the tunnel blasting much information was taken.

BRIEF HISTORY AND EARLY DEVELOPMENT OF DISTRICT

In 1890 John T. Dyer, operating a limestone quarry at Howellville, was forced through the demands of the railroads to seek harder rock for ballast. He delegated several of his men to scour the country for stone to meet these requirements. One of these men, William Johnson, superintendent of the Howellville quarry and former resident of Berks County, recalled that at the time the Willmington and Northern Railroad was being built, several contractors had encountered considerable difficulty in excavating a deep cut through a hard rock about 1 mile south of Birdsboro. Johnson investigated this rock and found it to possess the qualities for which he sought. Dyer approved of the location and the railroads

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2 - One of the consulting engineers, U. S. Bureau of Mines.

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were satisfied with the hardness of the rock. Therefore, after securing a lease to the property in 1894, a plant was erected and started.

In 1911, because of the necessity of increasing production and the desire to secure a site on another railroad, the John T. Dyer Quarry Co. purchased a property on the same trap rock dyke about 3 miles to the west.

In 1906 competitors started operations about 3 miles east of the Birdsboro quarry. This property was taken over by the John T. Dyer Quarry Co. from the Birdsboro Stone Co. in 1925 and is now known as the Monocacy quarry.

GEOLOGY

The rock quarried by the John T. Dyer Quarry Co. is known as trap rock. Trap rock is a general term used to designate all kinds of dark basic igneous rocks, especially those having the finer texture. Frequently certain granites are incorrectly classified as trap rock because of their dark color. The principal distinction between trap rock and granite lies in the difference of their chemical compositions; trap rock is a basic igneous rock and granite is an acid igneous rock. Any acid igneous rock, therefore, regardless of color, would be more correctly classified as granite. The binding qualities of these acid rocks are poor.

At the quarries located at Trap Rock, Clingan, Monocacy, and Monocacy Hill the rocks were once in a fluid or molten condition and while in this state were forced up through fissures in other rocks to the position they now occupy. They occur as dikes where they have solidified in vertical fissures, and as immense sills or lenses where they have been forced into and between the strata of horizontal sedimentary rocks.

CHARACTERISTICS OF ROCK

The rocks are somewhat gray in color, of medium coarseness and are crystalline basic rocks belonging to the species of trap rock known as gabbro. Throughout the immediate vicinity of the quarries the strata of sedimentary rocks has been dislocated, faulted, and upturned by the intruded igneous rocks and by the various movements which have later taken place. Being more resistant than the sedimentary rocks the trap gives rise, through erosion, to prominent topographic features.

In many places there is no overburden, especially on the tops of the several hills where large boulders of trap rock are at the surface; but passing to the lower slopes the overburden increases and red shale is usually found. This lack of overburden is due to the fact that trap rocks resist erosion better than the surrounding rocks.

The color varies in proportion to the amount of feldspar, ferromanganese, hornblende, and other minerals present. The proportion of these minerals also determines the hardness of the rock. Compression tests were made by Prof. H. C. Berry of the University of Pennsylvania showing the following results:

	Average ultimate crushing strength, pounds per square inch	Number of specimens tested
Clingan	22,956	9
Birdsboro	19,622	9
Monocacy	21,873	9

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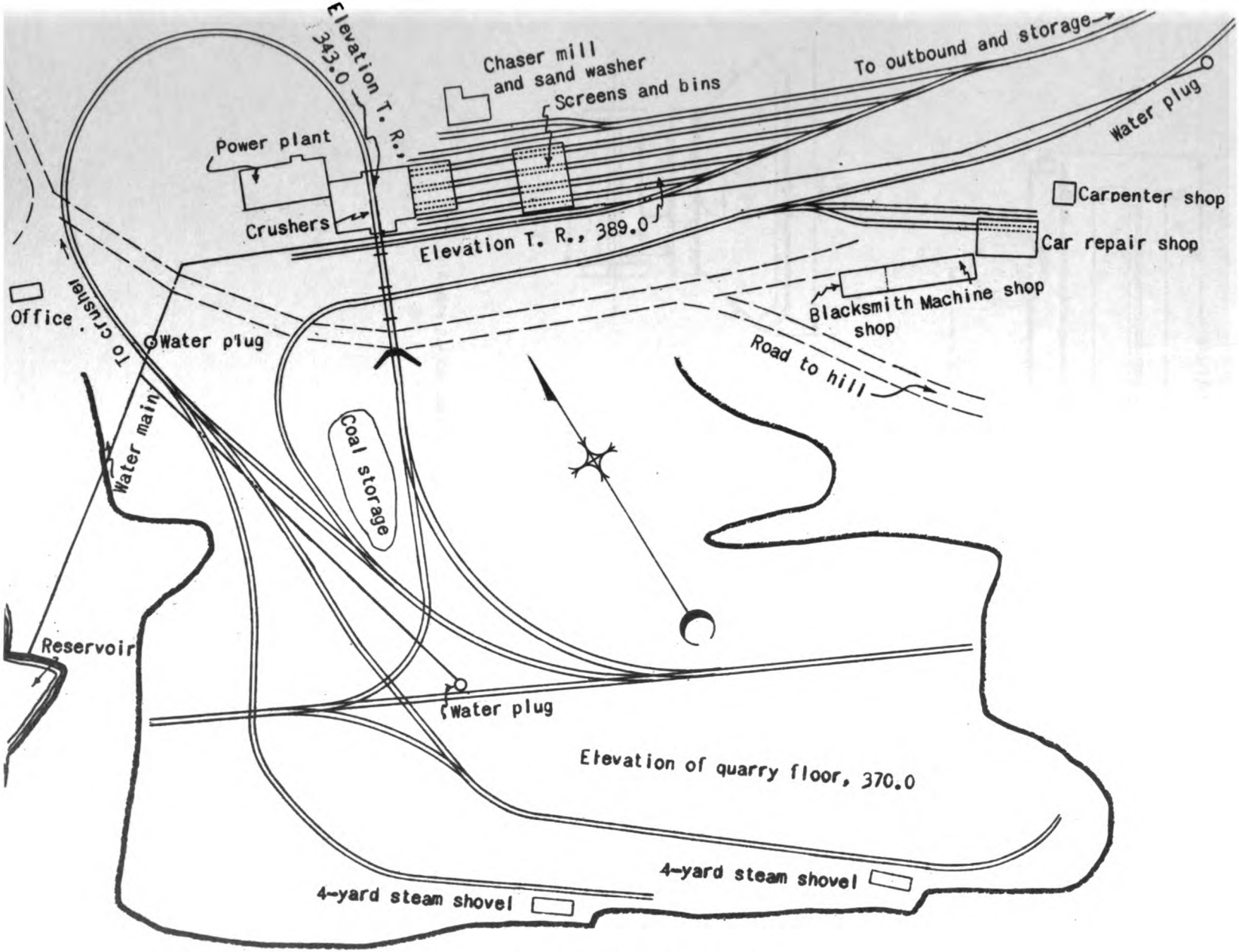

Figure 1.- General plan of quarry

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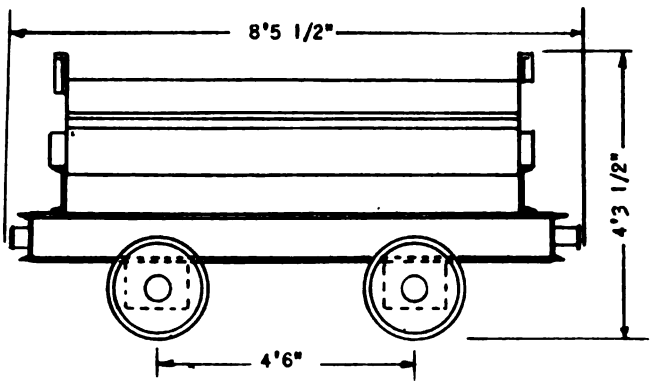

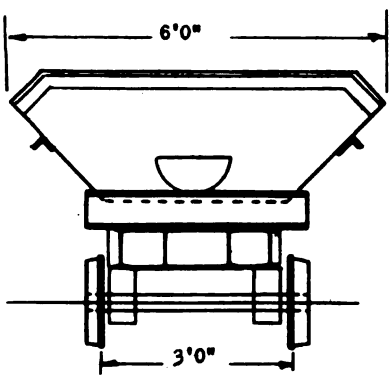

Figure 2.- Car used for stripping

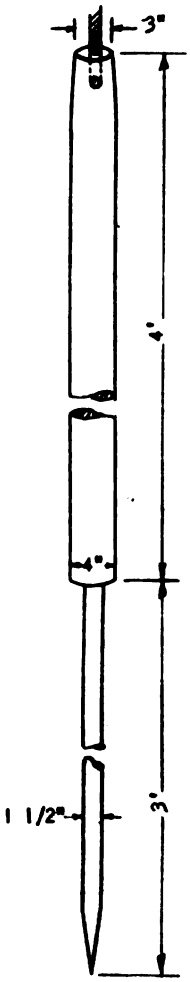

Figure 3.- Wooden tamping block for tamping charge in well drill hole

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Throughout the deposit the presence of joints is pronounced. These joints are cracks or fissures which divide the mass into blocks, fitted together like masonry. The main system of joints roughly trend in the direction of south 40° west and are very nearly vertical. At the Monocacy, Clingan, and Monocacy Hill quarries these joints furnish excellent lines of parting and stand out as smooth vertical walls often extending for a distance of 50 feet or more.

At the Birdsboro quarry this jointing is largely obliterated by the effect of slickensides. These slickenslides were the result of compression which caused the rocks to move or slide upon each other and often crumbled the rock into smaller units. This accounts for the ease of fragmentation at this quarry. Throughout the quarry there are no well developed fissures or caves except in one place where a depression was caused by the erosion of a zone of weakness in the rock which was then filled with clay. This zone of weakness developed through the folding and crushing of the rock.

There is another type of joints or faults which are roughly at right angles to the main joints described which incline about 45° NW. This type of joint is not so well defined as the main system, but is fairly well marked in all of the deposits.

This general trend of joints tends to make the rock break up in roughly rectangular blocks varying in size from dimensions of fractions of an inch to 5 by 7 feet. An exception to this occurs in the center of the Clingan quarry where jointing is poorly developed so as to cause fragmentation to be very poor, thus increasing the secondary drilling and blasting costs.

ESTIMATION OF TONNAGES

The tonnage of unquarried rock available and the life of each plant have been estimated as follows:

	Tons	Life in years
Birdsboro	101,500,000	440
Clingan	11,000,000	60
Monocacy	160,000,000	330
	272,500,000	

MINING METHODS

A plan of the quarry is shown in Figure 1.

Stripping

The overburden averages about 5 feet in depth. An Osgood 29 caterpillar shovel with a 1-yard bucket loads the dirt into rocker dump cars, having a capacity of 2 tons, which are drawn by a 4-ton Plymouth gasoline friction-drive locomotive upon 36-inch gage portable tracks. About 250 yards of dirt, which has no value, is removed daily and hauled to the dump about 1,000 feet away. Since the job of stripping or removing overburden is intermit tent, the caterpillar shovel performs many other tasks in and about the quarry and is therefore classed as service equipment; that is, equipment that does work for other departments. Details of the cars used in stripping are shown in Figure 2

Well Drilling

Churn drilling is done by a Loomis clipper and a Keystone drill belt driven by an

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11-hp. Westinghouse slip ring motor and a 15-hp. Allis Chalmers slip ring ball-bearing motor, respectively, using 8-inch "Carr" bits made of high-grade drill steel. The drilling speed is about 8 inches per hour, the holes being spaced 35 feet apart and 40 feet from the bench face. This spacing is necessary due to the columnar formation, the hardness of the rock, the height of the face (maximum being 310 feet and minimum 225 feet), the large number of holes shot simultaneously, and the fragmentation desired. The drills usually work from side to center, drilling holes 8 inches in diameter to a depth of 10 feet below the level of the quarry floor.

Due to the height of the face and the type of joints, the drills have a tendency to follow these joints or cracks so that many holes are lost before reaching the desired depth; therefore well drilling is a very expensive operation.

Tunnel Drilling

To reduce this expense, tunnel or gopher drilling has been tried, and up to the time of this writing it has been found very successful. This type of drilling is done with I.R.-L-74 drifter drills which weigh 94 pounds mounted. Compressed air is delivered at a minimum pressure of 75 pounds per square inch at the drill. The average air consumption is 75 cubic feet per minute per machine, including line loss, at peak load. One-inch hexagon hollow drill steel is used to drill the holes which are 1-1/2 inches in diameter and 4-1/2 feet long. A two-man crew working a 10-hour shift would advance from 20 to 25 feet per week, mucking, drilling, and shooting in one shift. The method used was to make a five-hole burn-out cut with 7 trim holes (fig. 5) The holes are so arranged that the size of the tunnel will be 4 feet wide and 5 feet high, enabling loading and mucking to be done with ease.

Blasting Well Drill Holes

Sixty per cent 7 by 24 inch quarry gelatin, with double countered cordeau, is used in blasting the well drill holes. Springing is not practiced as the holes are drilled large enough to accommodate the powder to lift the toe. Cordeau is lowered with the first cartridge of powder, the balance of the powder is dropped in the hole, and distance is measured after 10 cases have been loaded. Two crews, usually consisting of powderman and helper, load the holes; 20 cases of 7 by 24 inch cartridges are loaded in 8 minutes. After the holes are loaded, dirt is poured in and left to settle.

If a hole becomes plugged while loading, tamping blocks similar to those shown in Figure 3 are used. These blocks were developed by the men at the plant after encountering difficulties in the use of others. Their superiority is that the pointed bottom section will punch through the clogged dynamite rather than drive it down by compression, while the shape and length of the upper section tend to force the blow near the center of the dynamite rather than against the walls. Also blocks of this shape are not so likely to damage cordeau or dislodge loose rock from the sides of the hole.

The routine of the work of loading a hole after the dynamite has arrived by railroad and our own locomotives have placed cars on the quarry floor is:

1. Unloading freight cars and loading truck.
2. Truck to skip car.
3. Skip car to hole.
4. Bail water out of holes

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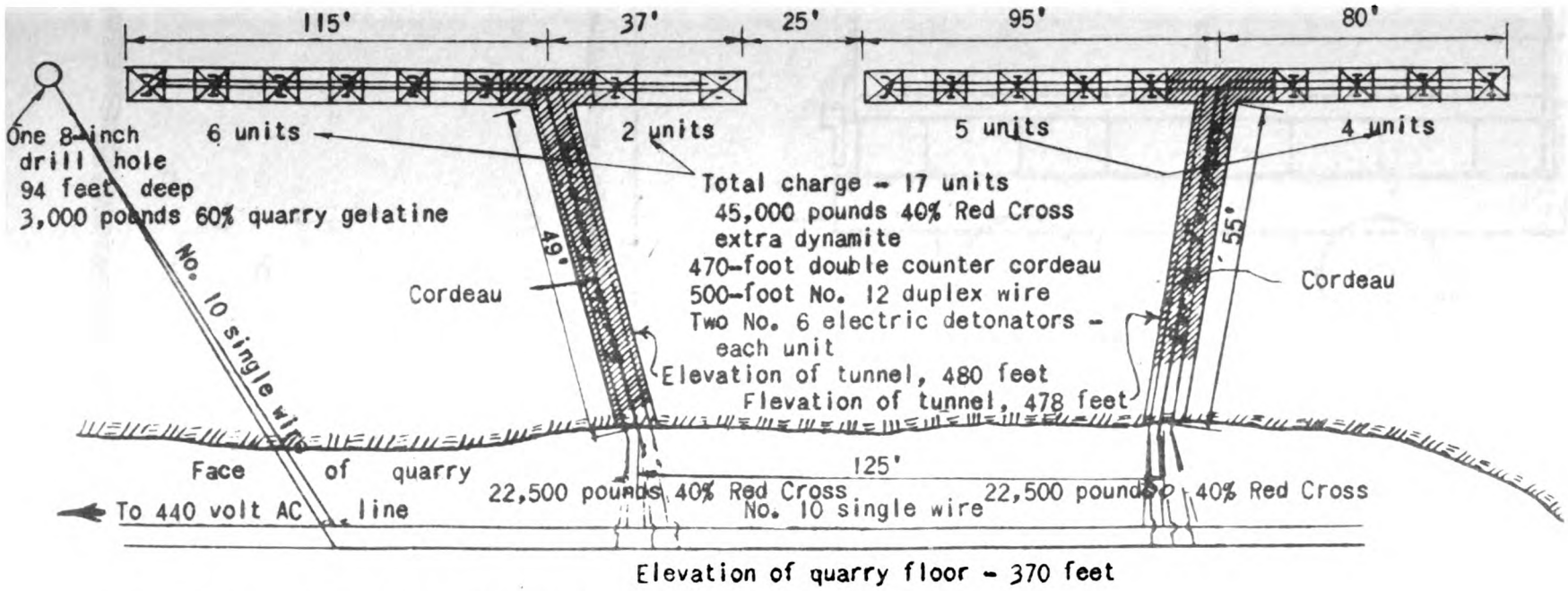

Overburden on tunnels, 120 to 180 feet
Estimated production from blast, 300,000 tons

Figure 4.- Plan and loading of coyote tunnels and drill-hole shot on April 30, 1930

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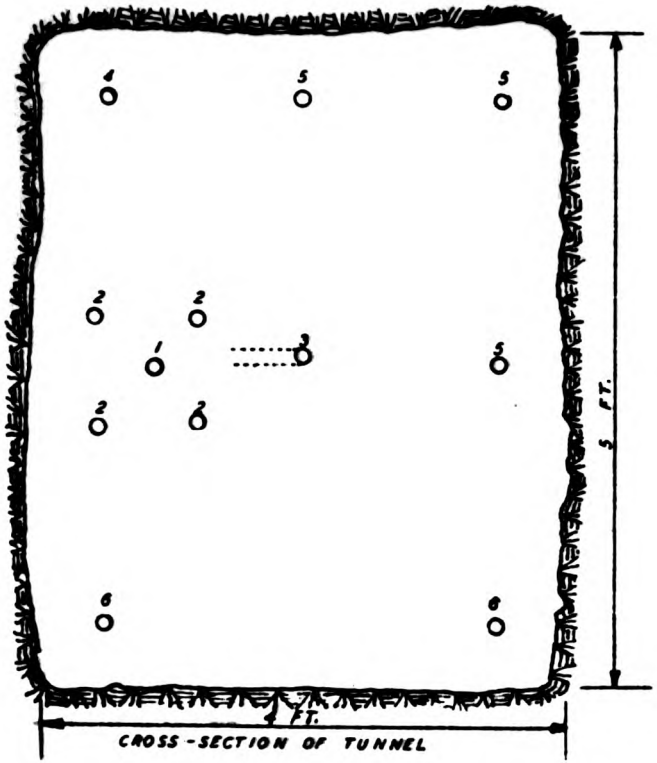

Hole No.	Order of firing
1	Unloaded
2	First
3	Second
4	Third
5	Fourth
6	Fifth

Figure 5.- Layout of drill holes in Coyote tunnels by burn-cut method; all holes are 4.5 feet deep

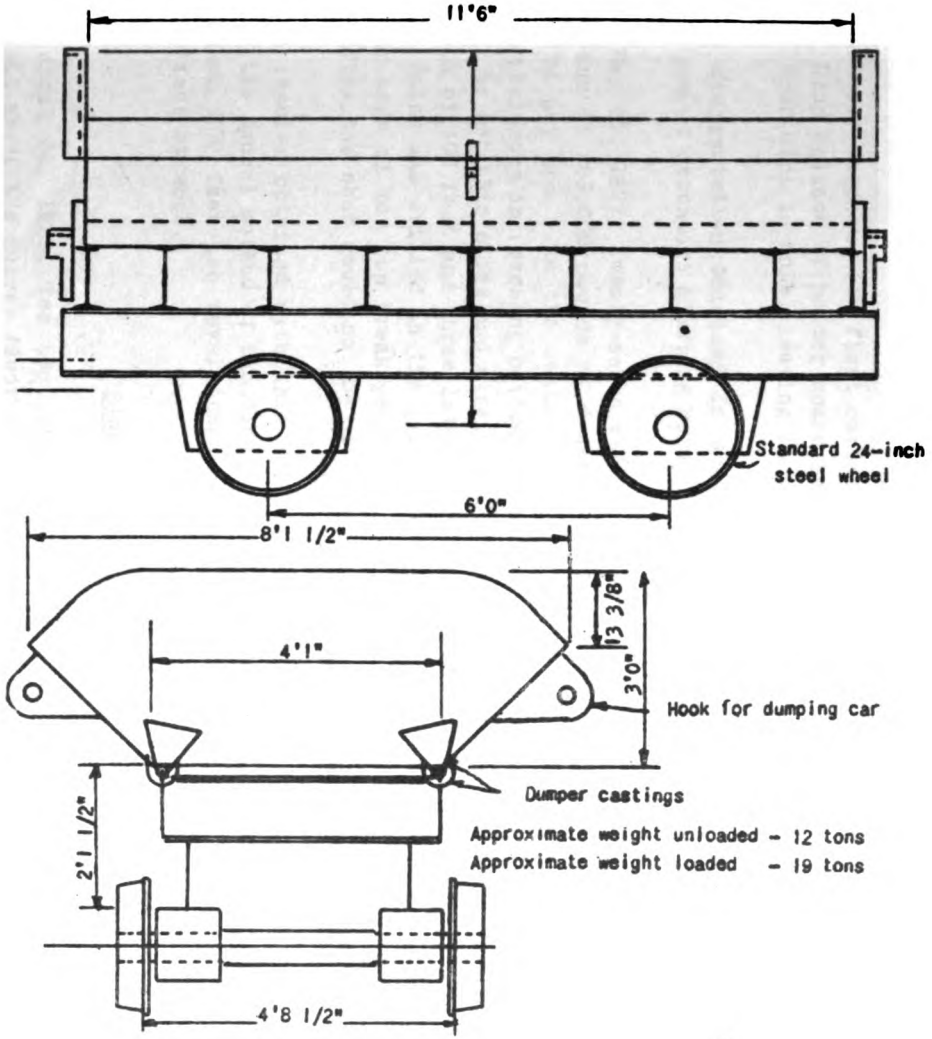

Figure 6.- Quarry cars

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5. Lower cordeau with first cartridge.
6. Drop balance of powder measuring every 10 cases.
7. Pour dirt in hole, leaving it to settle.

The fragmentation obtained is usually from a fraction of an inch to 60 by 84 inches, a minimum of secondary blasting being necessary because of the large primary crusher.

On May 30, 1927, twenty-seven well drill holes and one tunnel were shot simultaneously by means of 169,000 pounds of dynamite, bringing down 1,000,000 tons of rock at a cost of $0.0784 per ton. In the center of the quarry, where the face is 270 feet high, trouble was experienced in reaching bottom so that for four or five years it was not blasted. In an endeavor to get this stone and straighten up the face, a tunnel was driven in this section to a depth of 108 feet and three laterals were driven on each side. In addition a line of well drill holes was drilled on the left side face with a few 100-foot holes back of the tunnel to take care of the top breakage, to throw the top stone, and to make sure that the broken bank after the shot would not be dangerously high.

The results obtained with this shot were so satisfactory that it was decided to continue with the tunnel method of blasting. Well drilling has been discontinued, and where the face exceeds 200 feet two level tunnels are driven so as to give a burden over each tunnel of 100 feet or more.

Blasting Tunnel

On April 30, 1929, two top level tunnels were fired. The tunnel portals were started 120 feet above the quarry floor and were driven level. At the west end where a considerable end break was to be expected, a 93-foot well was drilled to give better breakage in this section and was loaded with 2,500 pounds of 60 per cent quarry gelatin. This, added to the load in the tunnels, made a total load of 44,500 pounds. The main tunnel load was 40 per cent Red Cross Extra dynamite. The plan and loading of Coyote Tunnels and drill hole shot on April 30, 1930, are shown in Figure 4.

The problem of supplying the powder and stemming to the tunnels was solved by the use of the Osgood 29 shovel which was fitted with a crane boom and mounted on the top ledge of the quarry. The dynamite in the original boxes was lowered to the tunnel portals, where the boxes were opened and the 5 by 16 inch cartridges stacked in wheelbarrows and wheeled over a board flooring into the tunnel. In this manner approximately 200 to 350 pounds of dynamite was taken in at a time and piled like cordwood in the unit for which it was intended.

Number 12 waterproof duplex leading wire was strung in each tunnel, and a separate circuit was made for each wing. This was supported at 12-foot intervals by screw eyes in the roof. The screw eyes were placed in bolt expanders driven into drilled holes in the roof. Two No. 6 electric detonators were placed in each unit and connected in parallel with the wing tunnel circuit. As an additional precaution a line of cordeau was run to the portal of the main entry and another line of cordeau was used to connect the last unit of each wing with the last unit of the opposite wing.

Single No. 10 leading wire was used to connect both tunnels and the well drill hole all in parallel, and the shot was fired from a 440-volt a.c. line.

No stemming was used between the wing units, but at the junction of the main tunnel and the last wing unit, powder boxes filled with dirt were piled to the roof to act as a

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bulkhead and the balance of the tunnel was filled to the portal with dirt. The use of dirt as stemming in this shot is in sharp contrast with the use of water in the tunnel shot on May 30, 1927.

This tunnel blast was very successful, as it brought down 250,000 tons of rock at a cost per ton of $0.0336 as compared with $0.0784 per ton, the cost of the shot on May 30, 1927.

Detailed cost of tunnel shot, April 30, 1930

	Amount	Cost per ton	Cost per foot
Tunnel Drilling			
Labor operating	$826.30	$ .0033	$1.9172
Power	591.32	.0024	1.3720
Labor repairs	684.70	.0027	1.5886
Material repairs	242.67	.0010	.5630
Explosives	209.77	.0008	.4867
Shops	9.84		.0228
Tools and miscellaneous supplies	135.44	.0006	.3143
Total	2,700.04	.0108	6.2646
Well Drill			
Labor operating	177.00	.0008	1.9032
Power	31.67	.0001	.3405
Labor repairs	34.65	.0001	.3726
Tools and Miscellaneous supplies	.22		.0024
Lubricants	4.19		.0451
Shops	25.01	.0001	.2689
Total	272.74	.0011	2.9327
Stripping			
Labor shovel	254.04	.0010	-
Coal	93.00	.0004	-
Labor repairs	119.26	.0005	-
Tools and miscellaneous supplies	4.56		
Shops	6.29		
Total	477.15	.0019	-
Explosives	4,956.91	.0198	-
Total cost	8,406.84	.0336	-

Tons shot	250,000
Well drill feet	93
Tunnel feet	431

Blasting Secondary

Twenty-five to thirty per cent of the rock on the quarry floor exceeds a size of 60 by 84 inches and therefore requires secondary blasting. Mud capping or block-holing are the methods used in secondary blasting. The size and shape of the boulder govern the posi-

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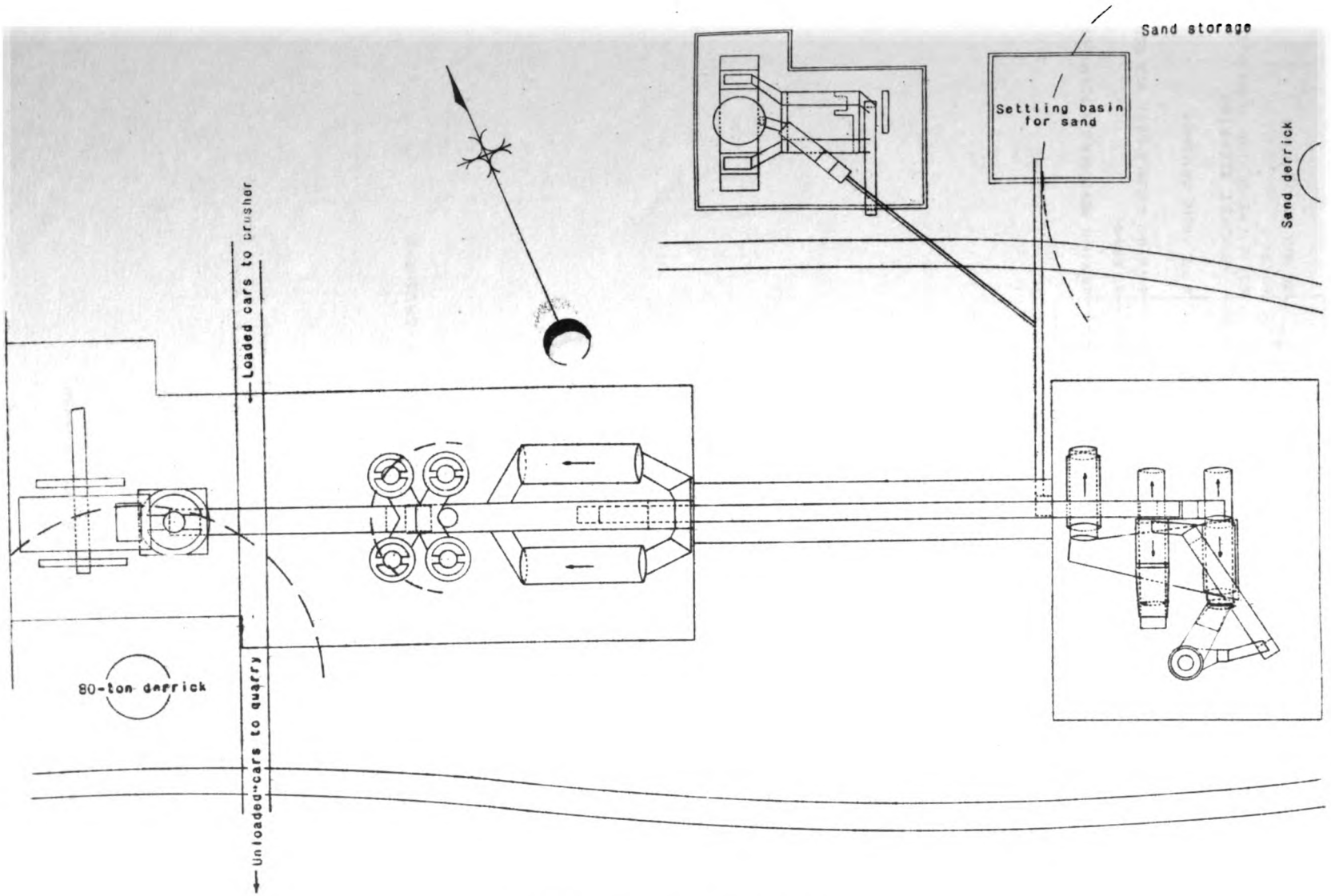

Figure 7.- Plan of crushing plant

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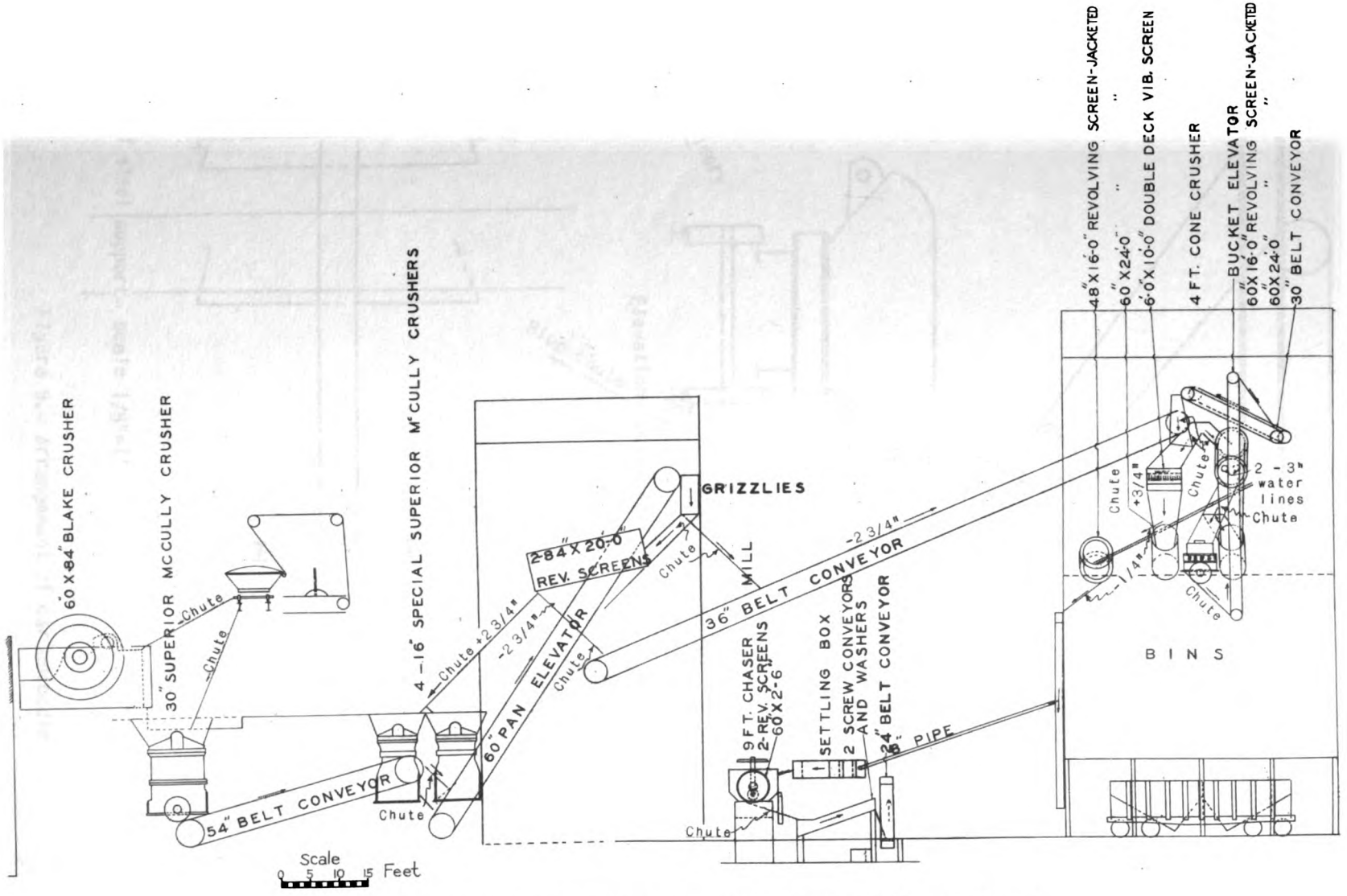

Figure 8.- Elevation of crushing plant. For additional details see: Plan of Crushing Plant and Flow sheet of Crushing Plant

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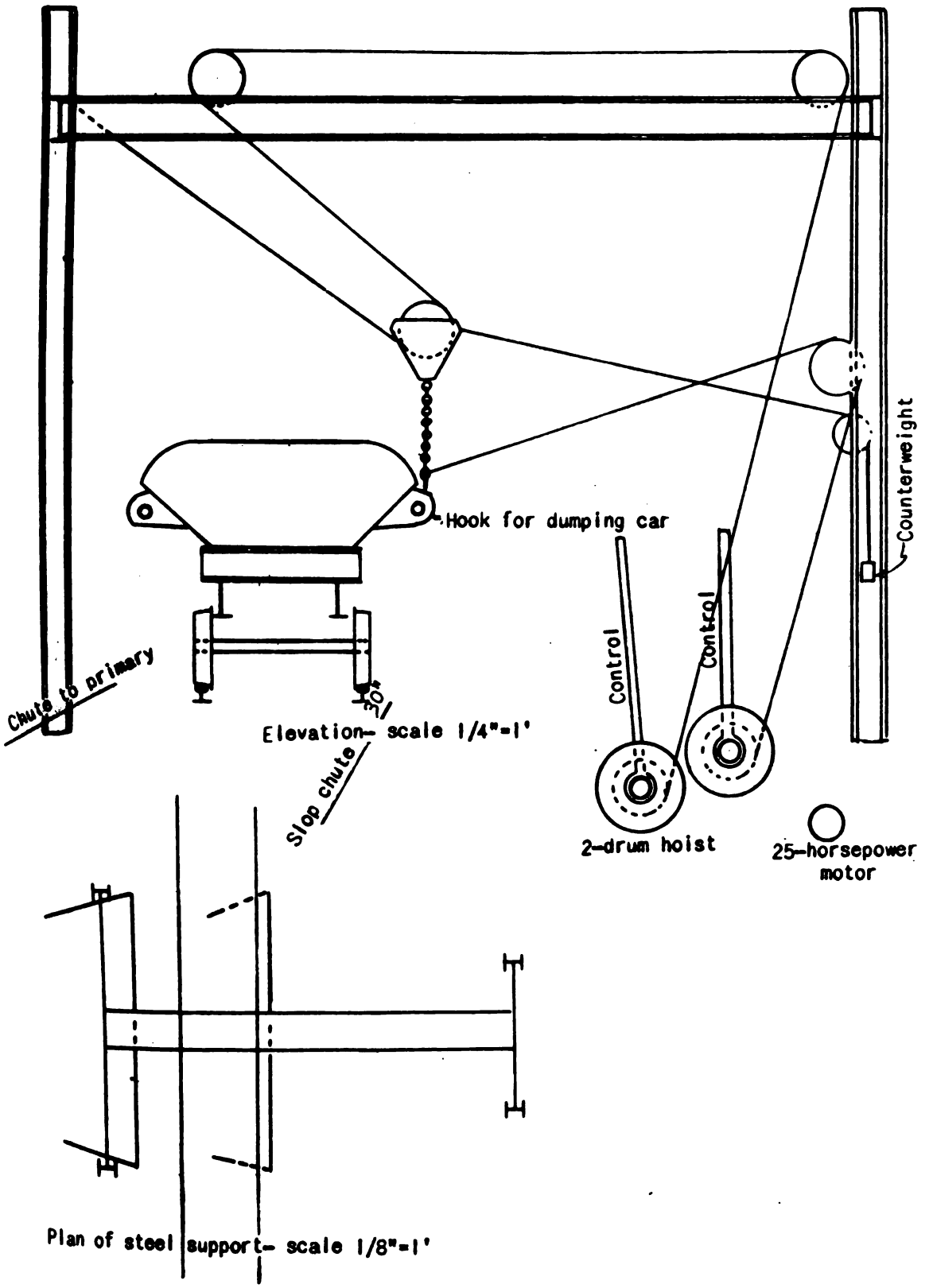

Figure 9.- Arrangement of car unloader

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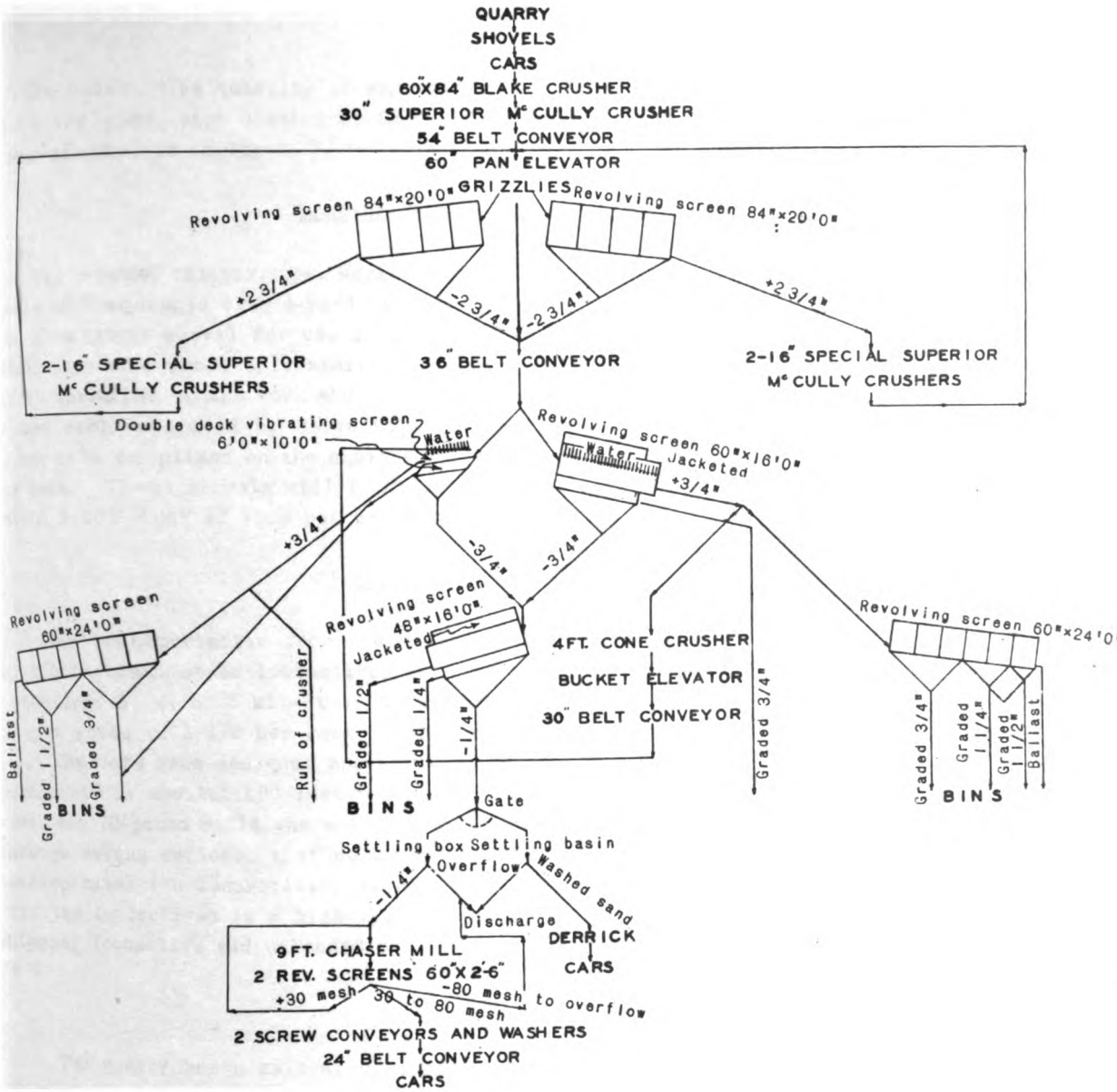

Figure 10.- Flow sheet

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tion of the holes. The quantity of explosives used in secondary and primary blasting averages about the same, each costing $0.02 per ton. Charter oak fuse, with a burning speed of 1 foot per minute, is employed.

Loading Stone on Quarry Floor

Two steam, railway type, Marion Osgood 120 and Bucyrus 950 shovels mounted on traction wheels and equipped with 4-yard dippers, are used in loading rock. The idea of traction wheels on a railway shovel for use in quarry work was developed at this quarry, the advantages being that the greater flexibility of the shovel gives approximately 50 per cent more capacity by speeding up the work and that four laborers are eliminated on each shovel. These shovels are each operated by three men - an engineer, a craneman, and a fireman, and a utility man acts as pitman on the shovels and as a powderman's helper when secondary blasting is being done. These shovels will load eight cars of 9 tons capacity in five minutes, averaging about 2,000 tons of rock per day each.

Transportation to Crusher

The transportation from the quarry floor is taken care of by four H. K. Porter 18-ton, saddle-tank, steam locomotives with 4-wheel drive of standard gage. These locomotives each draw 3, 4, or 5 all-steel cars with flat bottom and sloping sides of 10 tons capacity up a grade of 1-1/2 per cent to the crusher and down a grade of 4 per cent from the crusher. The cars were designed and built at the plant. The distance from the quarry face to the crusher is about 1,000 feet. Eighty-five-pound rails are used where the tracks are permanent and 70-pound rails where they are temporary. The locomotives make a complete circle through spring switches that do away with the need of a brakeman and switchman. Each engineer operates the locomotives, fires, takes water, and lubricates his cars. The fuel used for the locomotives is a high volatile coal which is delivered on the quarry floor by the shipping locomotive and unloaded by a crane. Details of the quarry cars are shown in Figure 6.

Drainage

The quarry has a natural drainage. The surface water flows out from the quarry face to a stream 30 feet below the floor.

CRUSHING PLANT

A plan and elevation of the crushing plant are shown in Figures 7 and 8.

Car Unloader

An electric hoist, built at the plant, driven by a 25-hp. G. E. squirrel-cage motor dumps the stone from the quarry cars into the primary crusher. The arrangement for unloading cars is shown in Figure 9.

Flow of Stone

The flow sheet of the plant is shown in Figure 10.

The stone after leaving the quarry cars flows through the following equipment:

1. 60 by 84 inch Blake crusher.
2. 30-inch Superior McCully gyratory crusher.
3. 54-inch conveyor belt.
4. 60-inch elevator bucket.
5. Grizzlies.

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6. Two 84-inch scalping screens.
7. Four 16-inch special crushers.
8. 36-inch conveyor belt.
9. Discharge Split Feed:
   Vibrating screen.
   60-inch by 16-foot screen.
10. Washing.
11. 60 inch by 24 foot sizing screens.
12. 48 inch by 16 foot revolving screens.
13. Symons 4-foot cone crusher.
14. Elevator vertical.
15. Chaser mill.

Primary Crusher

The primary breaker is a 60 by 84 inch Blake jaw crusher, manufactured by the Power and Mining Engineering Co., with an opening of 11 inches at the discharge. This machine has been rebuilt at the plant to meet the special requirements necessary in the crushing of hard rock. It is driven from an extension shaft, one end of which is connected through a flexible coupling to 500-hp., G. E. slip-ring, variable-speed motor and the other end through a similar coupling to a 500-hp. G. E. low starting torque synchronous motor.

The induction motor is for starting and emergency. In starting when the extension shaft has reached synchronous speed the synchronous motor is thrown in and the induction motor is cut out. Thus under running conditions the induction motor is idling on the line. The use of the 500-hp. synchronous motor is necessary to improve the power factor and provide sufficient power to meet peak loads. The 30-inch Superior McCully gyratory crusher also receives its power from this source by belt drive.

30-inch Superior McCully Gyratory Crusher

The 30-inch Superior McCully gyratory crusher is manganese-fitted throughout and has a spider which was specially designed at the plant. The feed to this crusher is by gravity and is directly underneath the primary jaw crusher. The discharge end has an opening averaging about 4-1/2 inches from which the stone is discharged onto a 54-inch conveyor belt.

54-inch Conveyor Belt

Stone averaging in size from a fraction of an inch to approximately 5 inches is carried to the 60-inch elevator by a 54-inch rubber conveyor belt 88 feet long driven direct by a 25-hp., G. E. squirrel-cage motor on a speed reducer, having an hourly capacity of about 600 tons.

60-inch Elevator

Power is transmitted to the 60-mesh elevator by a 150-hp. G. E. induction motor through a chain drive and spur gear reduction. The elevator inclines about 70°, is 74 feet center to center, equipped with 83 buckets, and carries the stone from the 54-inch conveyor belt to the two grizzlies. This elevator, which was also designed at the plant, has double the capacity of the previous elevators and has cut the speed down about 40 per cent.

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Grizzlies

The scalping screens are relieved of some of the fines by two grizzlies placed at the head of the 60-inch elevator and made of perforated plates having round holes of 2-3/4 inches.

84-inch Scalping Screens

The two 84-inch scalping screens are 20 feet long and are driven by a 75-hp. G. E. motor through a silent chain drive. These screens have been built from patterns and drawings made at the plant and consist of four sections; the first three sections have 3-inch round openings and the last section has a 3-1/2-inch square opening.

16-inch Special Superior McCully Crushers

Four special Superior McCully crushers, each driven by 150-hp. Ideal motors direct-connected with flexible couplings, receive the stone which is rejected on the two 84-inch scalping screens, reducing the size to 1-3/4 inches, which is the discharge setting of the crusher. The discharge from the 16-inch crushers is returned to the 60-inch elevator and thence to the 84-inch scalping screens, thus forming a closed circuit.

36-inch Conveyor Belt

The minus from the scalping screens is delivered on to a 36-inch rubber conveyor belt and carried for a distance of 100 feet to the screening and bin building. This conveyor, 110 feet long, inclines 22° and is driven from a line shaft in the screen building by the motor which also drives the 2 revolving screens.

Vibrating and Revolving Screens

Stone is delivered by means of a split feed to a 60-inch by 16-foot Allis Chalmers revolving screen and a 6 by 10 foot heavy duty, double-deck Niagara vibrating screen.

The 60-inch by 16-foot screen is equipped with round perforations of 1-1/4 inches for the full length and jacketed with perforations of 7/8 inch. This screen and the two 60-inch by 24-foot screens are driven from line shafts by means of two 75-hp. G. E. motors. The rejects from this screen are delivered to the 60-inch by 24-foot revolving screen. The rejects from the outer jacket are delivered to the commercial 3/4-inch bins. The minus from the outer jacket is delivered to the 48-inch by 16-foot screen.

The vibrating screen is equipped with wire cloth openings on the top deck of 1-1/8 inches and 11/16 inch on the bottom deck and is driven by a 7-1/2-hp. G. E. motor. The rejects from the upper deck are delivered to the 60-inch by 24-foot revolving screen. The rejects from the lower deck are delivered to the commercial 3/4-inch bin. The minus from the lower deck is delivered to the 48-inch by 16-foot screen.

Washing

After the stone leaves the 36-inch conveyor belt and is received by the above screens the stone is washed by the spray method. The water is received by means of gravity through pipes which are 10 inches in diameter at the reservoir on top of the quarry and 5 inches in diameter at the crusher.

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60-inch by 24-foot Sizing Screens

Rejects from the 60-inch by 16-foot revolving screen and the 6 by 10 foot vibrating screen are delivered by means of gravity on steel chutes to two 60-inch by 24-foot Allis Chalmers rebuilt screens. These two screens are each equipped with six sections, two of which have round perforations of 1-1/4 inches and the other three having round perforations of 1-3/4 inches. They are driven from line shafts by the two 75-hp. G. E. motors which also furnish the power for the 60-inch by 16-foot screen. The rejects from these screens are emptied into the ballast bins.

48-inch by 16-foot Revolving Screens

The minus stone from the vibrating screen and the 60-inch by 16-foot revolving screen is delivered by means of gravity to a 48-inch by 16-foot revolving jacketed screen which has 1/2-inch round perforations on the inside and 1/4-inch round perforations on the outside. The two 75-hp. G. E. motors also supply the power for this screen. The minus 1/4-inch stone and water which passes through is led outside the bin building by means of a sluice and discharged into a 20 by 20 foot concrete pit. The overflow from this pit, consisting of water and stone dust, passes to a stream and the sediment in the pit is picked out by a clamshell bucket and placed on the sand storage pile, on cars for shipment, or sent to Chaser mill for further reduction.

Symons 4-Foot Cone Crusher

The 4-foot cone crusher is an auxiliary crusher and is set at the discharge end of the 60-inch by 16-foot revolving screen. When the demand is large for small sizes, the rejects from the 60-inch by 16-foot screen instead of going to the 60-inch by 24-foot screens are diverted by means of a steel chute to the 4-foot cone crusher. After passing through this crusher the stone is lifted by means of a vertical elevator to the 6 by 10 foot vibrating screen, from which it passes over the same screens as previously explained. A 200-hp. Westinghouse synchronous motor furnishes the power for this crusher, but the plant is charged with a rating of only 100 hp. by the electric company from which the power is purchased.

Vertical Elevator

A continuous bucket elevator, manufactured by the Chain Belt Co., with a capacity of 150 tons per hour and driven by a 25-hp. G. E. motor carries the stone from the 4-foot cone to a short conveyor which discharges on to the 6 by 10 foot vibrating screen. This bucket elevator has a capacity of 150 tons.

Chaser Mill

At present a 9-foot chaser mill, wet type, manufactured by the Lewistown Foundry and Machine Co., is being installed. This mill will be belt-driven by a 30-hp., G. E. squirrel-cage motor and is expected to produce 125 tons daily through 30 mesh.

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Approximate tonnage passing over each screen, by sizes

Scalping screen (each)	Tons per hour	Average life
Minus 3 inch	140	1 to 3 years
Plus 3 inch	100	
	240	
Grizzly		
Minus 2¾ inch	60	
Plus 2¾ inch	240	
	300	
Vibrating screen		2 to 3 months
Over upper deck:		
Minus 3 inch plus 1-1/8 inch	145	
Over lower deck:		
Minus 1-1/8 inch plus 11/16 inch	17	
Through lower deck:		
Minus 11/16 inch	37	
60 inch by 16 foot Screen		1 to 3 years
Over inner jacket:		
Minus 3 inch plus 1¼ inch	145	
Over outer jacket:		
Minus 1¼ inch plus 7/8 inch	17	
Through outer jacket:		
Minus 7/8 inch	37	
60 inch by 24 foot screen (Each)		1 to 3 years
Rejects:		
Minus 3 inch plus 1¾ inch	115	
Through second section:		
Minus 1¾ inch plus 1¼ inch	22	
Through first section:		
Minus 1¼ inch plus 7/8 inch	9	
48 inch by 16 foot screen		1 to 3 years
Over inner jacket:		
Minus 7/8 inch plus 1/2 inch	43	
Over outer jacket:		
Minus 1/2 inch plus 1/4 inch	12	
Through outer jacket:		
Minus 1/4 inch	19	

Summary

After reading the foregoing paragraphs one would naturally conclude that this plant is over-motored, as in nearly every case the motors are larger than required to drive the machinery at normal load and are larger than manufacturers of equipment ordinarily recommend. This would be true if the stone were not so extremely hard, thereby causing the peak load to exceed the average load. Maintenance costs have been reduced considerably by the use of larger motors to drive the equipment.

It will be noted that this plant supplies the demand for stone, though it makes only five sizes totalling 450,000 to 500,000 tons yearly. The five sizes are as follows:

1. Ballast through 3-inch retained on 1 3/4-inch.
2. 1 1/2-inch through 1 3/4-inch retained on 1 1/4-inch.

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3. 3/4-inch through 1 1/4-inch retained on 7/8-inch.
4. 1/2-inch through 7/8-inch retained on 1/2-inch.
5. 1/4-inch through 1/2-inch retained on 1/4-inch.

(Minus-1/4-inch sand is not included in production figures, since previous to this writing all of the sand produced had not been sold).

The perforations of the screens may be changed from time to time depending upon the size demanded.

The flexibility of the plant in supplying the demand for stone may be seen from the following maximum and minimum percentages of stone produced, which have been taken from the monthly production covering a period of four years.

Size	Maximum per cent	Minimum per cent
Ballast	61	20
1 1/2-inch	37	05
3/4-inch	67	10
1/2-inch	56	07
1/4-inch	08	01

Stationary Derricks

The placing and removing of equipment in the crusher hoist is done by a stiff-leg derrick of 75 tons capacity, having a 40-foot mast and a 55-foot boom with three blocks and wire cable (made by the Terry Manufacturing Co.) operated by a triple-friction drum, 18 by 30 inch, hoisting engine (manufactured by the National Hoisting Engine Co.) connected to a 75-hp. G. E. induction motor.

A 10-ton derrick building mounted with a 50-foot boom, manufactured by the Terry Manufacturing Co., driven by a 40-hp. Allis Chalmers motor, handles the scalping and secondary machinery.

Sand Derrick

The sand is removed from the concrete pit to cars or storage pile by an American hoist derrick with a 1-yard clamshell bucket driven by a 40-hp. G. E. motor.

Buildings

The crusher building is a steel-frame structure with double-pitched roof and concrete foundations. It covers a ground area of 5,087 square feet and has a volume of 229,932 cubic feet.

The bin and screen house is also a steel-frame structure having steel H columns on concrete as foundation and covers a ground area of 3,143 square feet and has a volume of 267,155 cubic feet.

Bins

The bins are arranged in such a manner that their contents may be drawn off through

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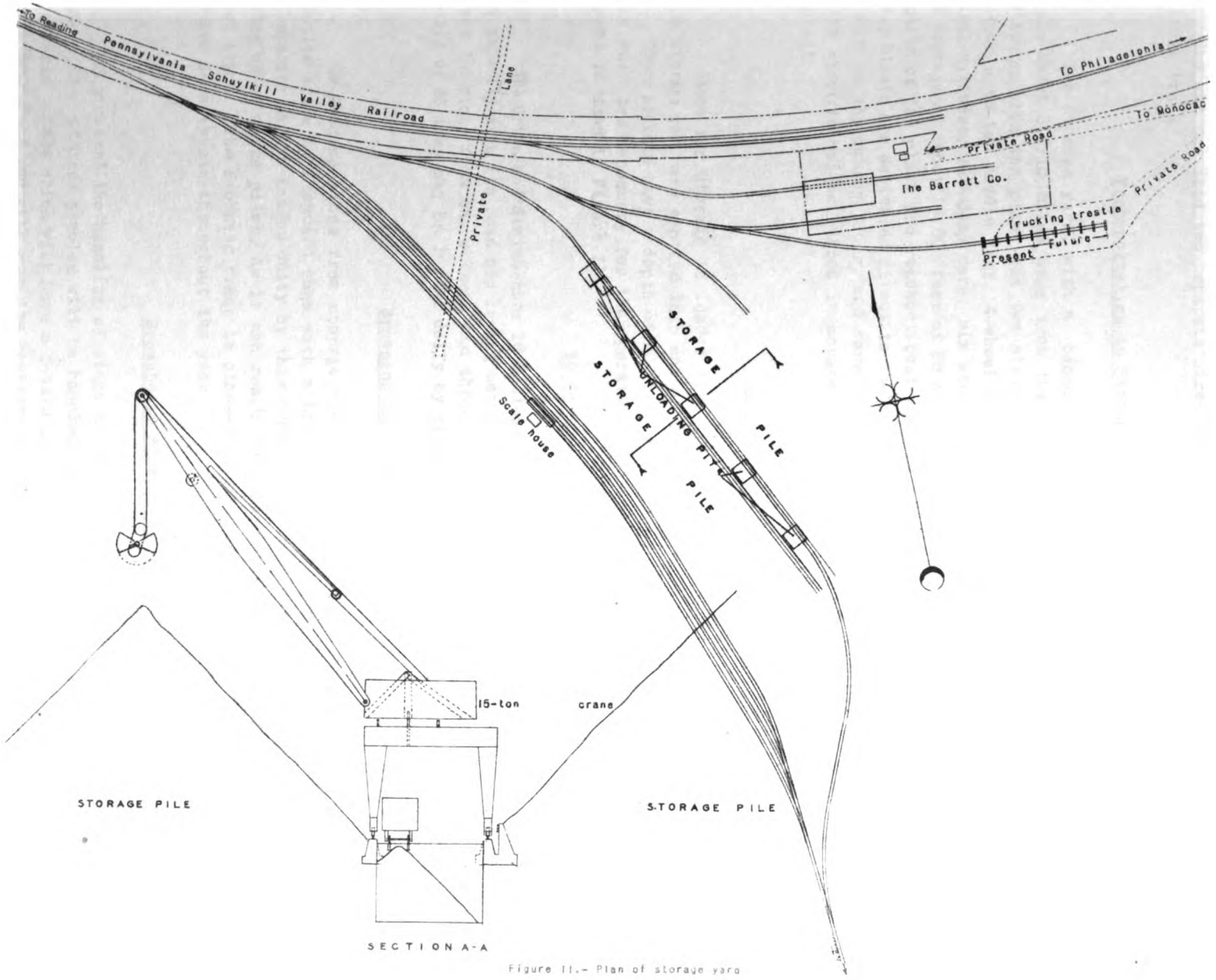

Figure 11.- Plan of storage yard

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gates. One man can load two separate sizes into two railway cars as each bin has its own individual track.

Transportation to Storage Yard and to the Carrier

The storage yard, with a capacity of 300,000 tons, and the Pennsylvania Railroad are about 2-2/10 miles away from the screening and bin house. To handle this transportation problem the plant has two steam locomotives, one 70-ton, 6-wheel standard gage, the other a 40-ton saddle tank, 4-wheel standard gage; three 30-ton Western all-steel, vertical-cylinder, air-dump cars; six steel hopper cars with a capacity of 50 tons; and a track footage of about 13,000 feet of 85 and 100 pound rails. These tracks are so laid that all parts of the plant are reached; coal for use of shovels in quarry, and explosives for primary blasts are delivered direct to the quarry floor, rip rap is loaded direct into railroad cars on the quarry floor, and service equipment such as the Browning locomotive crane and the electric welder, which is mounted on a standard-gage car, can reach all parts of the plant.

Storage Yard

Stone for storage is loaded from the bins into hopper cars which upon arriving at the storage yard are emptied into one of the five concrete pockets provided for the purpose. These pockets have a depth of 20 feet, are 30 feet square, and lie to the side of the tracks which are necessary for the operation of the 16-foot gage crane. A plan of the storage yard is shown in Figure 11.

16-Foot Gage Crane

The Orton and Steinbenner 16-foot-gage locomotive crane having a bucket of 3 cubic yards capacity with its road bed laying between the concrete pockets and the piles of stone, removes the stone from the pockets and throws it on its respective pile. Forty cars with a capacity of 50 tons may be loaded daily by this crane.

Browning Locomotive Crane

In loading stone from storage the 16-foot crane is also assisted by a Browning locomotive crane of standard gage with a bucket of 1-1/2 yards capacity. Ten cars of 50 tons capacity may be loaded daily by this crane. Besides loading stone it also aids in the clearing up of stone piles, as it can reach the stone which flows out of the reach of the 16-foot crane. The Browning crane is classed as service equipment, since it performs work for other departments throughout the year.

Brownhoist 30-Foot Gage

At present the handling of stone at the storage yard is undergoing a change. In the future the storage problem will be handled by a 15-ton Brownhoist, 30-foot-gage, electric portable crane which will have a 5-yard bucket. The tracks for this crane will extend for about 800 feet and will span the concrete pockets with the loading and unloading tracks for the railroad lying to one side of the pits. The piles of stone on both sides of the crane will be easily reached by means of its 100-foot boom. It is expected that the shipping capacity of the plant will be increased 100 cars per day upon the completion of the work now in progress.

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Power for the crane will be furnished through three single-rail conductors mounted on a 4-foot concrete wall and connected with contact shoes to the crane. The 4-foot concrete wall also acts as a retaining wall, thus increasing the storage capacity of the yard.

The crane will have the following electrical equipment:

2 - 100-hp., G. E. slip-ring, variable-speed, hoist motors operated with magnetic controls, dynamic and oil brakes; dynamic brake checks load. Oil brake holds load.

1 - 52-hp., G. E. slip-ring, rotary motor magnetic controls; rotating.
1 - 52-hp., G. E. slip-ring, travel motor, Drimi-type control.
1 - 52-hp., G. E. slip-ring, boom hoist motor, Drimi-type control; magnetic brake.

The installation of this crane and the laying of the foundation is being done by the regular employees of the plant.

Trestle

Another new addition which will take care of stone to be hauled by customers' trucks is the construction of a steel trestle equipped with eight 75-ton hoppers which will enable 24 trucks to be loaded at one time. This trestle was also fabricated and erected by the men regularly employed at the plant.

Scale House

The stone is weighed on a 150-ton-capacity scale, manufactured by the Standard Scale Co., by the shipping clerk who receives shipping instructions by telephone from the main office, located at Norristown, Pa., which are confirmed on the following day by mail.

MISCELLANEOUS DEPARTMENTS OF PLANT

The expense of other equipment and facilities of the plant may be divided into two classes, service and general plant expense.

The service class includes air compression, machine, blacksmith, welding, Browning locomotive crane and caterpillar shovel, while the general plant expense consists of superintendence, general yard, hotel, quarry dwellings, truck, and miscellaneous buildings costs.

The difference between these departments is that the service departments perform work for other departments, the costs of which can be distributed on the basis of man-hours, shovel-hours, etc., while the departments composing the general plant expense class also assist the other departments but the costs can not be allocated on any such basis.

Air Compression

Air is used for tunnel and secondary drilling, drill sharpening, and general repairs. A PRE-2 air compressor of 1,302 cubic feet capacity driven by a 210-hp. synchronous motor furnishes the main source of air. In addition to this there is a 14 by 12 inch ER-1-JR air compressor, located on top of the quarry, which is used for stripping purposes, and a 9 by 8-inch Type 20 portable compressor which furnishes the air for scattered jobs throughout the plant. In cases of breakdown, when a few men work overtime to repair, this latter compression is indispensable.

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Machine, Blacksmith, and Welding Shops

Throughout this paper it will be noted that nearly all of the equipment has been rebuilt and redesigned at the plant and that many new additions in equipment are being erected by the regularly employed men at the plant.

To do this it is necessary to have a well-equipped shop and to employ mechanics who understand the requirements and rough usage that equipment is put to in quarry work. When new equipment is purchased it is watched carefully to observe the possible weak spots so that they can be reinforced. Each part of a machine is investigated to determine whether repairs could be made more economically by the shops or by outsiders. Patterns are made of some of the cast parts in order to save time when a replacement is necessary. At the present time 725 patterns of this sort are on hand, some of which have been made at the shops. These shops also do work for the two other quarries belonging to the company which are located nearby.

Machine Shop

Castings of pinions, car axles, wheels, pistons and piston rings, well drill stems, shafting, motor bearings, etc., are ordered in the rough and are machined to meet the requirements of the particular job.

Blacksmith Shop

Bolts from 5/8 inch to 3 1/2 inches in diameter are made and threaded.

Drill steel is purchased in mill lengths, out of which drills of various lengths are cut.

Switch points, guard rails, crossovers, and frogs for the plant's railroads are fabricated.

All quarry cars are rebuilt.

Welding Shop

Practically all necessary machine work is done in the shops at considerable saving of time and money. Some examples of the work done follow:

Shaft on 60 by 84 inch primary crusher wore down to about 1 inch below size. Welders built the metal back to size.

Worn spiders on gyratory crushers have been built up, thereby saving a replacement.

Cylinder on locomotive has been rewelded and bored.
Crusher frames have been welded and rebored.
To carry on this work the shops are fitted out as follows:

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Woodworking Shop

1 - Band saw; 36-inch adjustable table 32 by 27 inches, throat 36 inches, with saw guide belt driven by a 10-hp. motor. Crescent Machine Co.
1 - Pneumatic drill for woodwork.
1 - Rip saw table; 36 by 54-inch blade, 22 inches diameter, adjustable table with guide. Atlantic Iron Works.

Machine Shop

1 - Lathe; 42-inch swing by 18-foot bed, double back geared, cone pulley drive, 10-hp. motor, silent chain drive. Schumacher and Boyd.
1 - Lathe; 28 inch swing by 26 foot bed, double back geared, quick change gear, taper attachment, two face plates, two steady rests, one following rest, chuck, countershaft. Schumacher and Boyd.
1 - Planer; 30 inch by 10 foot open side, horizontal and vertical heads, 10-hp. motor on bracket No. 543. Detrick and Harvey Machine Co.
1 - Shaper; 22 inch, 5-hp. G. E. motor, direct. Stockbridge.
1 - 6 foot radial drill; 10-hp. motor, direct. Dresser Manufacturing Co.
1 - Lathe; 16 inch swing by 8 foot bed, double back geared, cone pulley drive, 5-hp. motor, silent chain drive. F. E. Reed Co.
1 - Planer chuck; 13 inch. Skinner.
1 - Bench vise No. 289½; 6 inch jaws, combination jaw and pipe vise with swivel base. Charles Parker Co.
1 - Drill press No. 1029; 34 inch back geared, positive feed, pulley drive, driven by a 5-hp. G. E. motor, silent chain drive. W. F. and G. Barnes Co.
1 - Grinder; Double-disk 14 inch diameter, 2 inch face.
1 - Chain hoist; 10 tons, Yale and Towne Manufacturing Co.
1 - Hoist electric portable; 5 tons. Roeper.
1 - Pipe threading machine No. 3; Capacity of 1½ inch to 6, inch pulley drive, 5-hp. motor, silent chain drive. Williams Tool Co.
2 - Trolley runways; 4-Wheel trolley.

Blacksmith Shop

2 - Furnaces; 1 oil, 1 coal.
1 - Grinder; double-disk, 14 inch diameter, 2 inch face.
1 - Drop hammer; pneumatic 2 inch by 16 inch.
1 - Jib crane; with trolley for 5 inch I-beam.
1 - Shank and bit punch; Leyner-type IR-133.

Welding Shop

1 - Electric welding outfit; mounted on standard-gage railroad car; generator set, 500 ampere, 3 welders.
2 - Oxygen-acetylene cutting outfits.
1 - Punch or shear; single cap, 1½ inch throat, 55 inch No. 16081, type T244; direct-connected through gears to 5½-hp. motor. Long and Alstatter.

Portable Equipment

1 - Portable boring bar. Cincinnati Machine and Supply Co.

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1 - Electric portable drill; 1/2-hp. motor. Black and Decker.
2 - Corner pneumatic drills. Thor.
1 - Electric portable grinder, No. 90168, with 1/3-hp. motor. Van Dorn.
1 - Key seater, No. 2. Burr.
2 - Pneumatic riveting hammers. No. 90, "Little David." Ingersoll Rand Co.
The personnel of these shops is as follows:

4 machinists,
2 blacksmiths,
3 welders.

The overhead costs of the various jobs performed by these departments are distributed on the basis of man-hours. All labor and material are charged directly to the job.

Power

Electric power is purchased through the Associated Gas and Electric Co., and all parts of the plant are reached by the power lines. The kilowatt hours consumed are spread over the various departments, except crushing and screening, on the basis of the rated horsepower, taking into consideration the number of hours each motor operated during the month and charging the balance to crushing and screening. These figures are checked from time to time by placing a meter on each department, the electrician's time being charged direct to the job upon which he and his helpers are working.

Browning Locomotive Crane and Caterpillar Shovel

Since the Browning locomotive crane and caterpillar shovel have been previously explained nothing need be said at this point other than that the costs of operating are distributed over the various jobs upon which they work on the basis of crane or shovel hours. Depreciation is included.

GENERAL PLANT EXPENSE

Superintendence

Superintendence includes the salary of the superintendent, quarry clerk, all costs in connection with the safety program, and engineering.

General Yard

The general yard expense includes the costs of keeping the plant clean as a whole and any costs which can not be definitely allocated to a particular job.

Hotel

The hotel or boarding house provides the men who desire it with their dinner at a cost to them of $0.35 per meal, the company shouldering the balance of the costs. This scheme has repaid the company in more ways than one, as it provides a place for the men to meet and eat, thereby bringing about good fellowship. The men can get a hot meal in inclement weather, and in cases of overtime, due to breakdowns, the men are willing to work late

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knowing that they can secure a hot meal at the company's expense. The hotel also provides food for the company's annual outings when the three plants vie with one another for supremacy in athletic events.

Quarry Dwellings

In the vicinity of this plant there are 27 dwellings which are owned by the company and are rented to the employees at a nominal cost, the excess costs being absorbed by the company.

Truck

A Reo truck hauls the freight for the plant, carries the men to and from work, and does odd jobs in and about the plant.

Miscellaneous Buildings

The buildings grouped as miscellaneous are those in which material, spare parts, and patterns are stored.

Group and Health Insurance

After an employee has been with the company six months he is eligible for both group and health insurance without taking a physical examination.

The premiums on the group insurance are paid by the company, the amount of the insurance starting with $500 and increasing $100 every year the employee is with the company until the maximum of $5,000 is reached.

The premiums on health insurance are paid by the employees themselves. An amount of $1 per month entitles them to $13 per week sick benefits for 13 weeks after the first three days sickness.

SUPPLIES

All supplies except coal, explosives, and gasoline are charged direct to the department for which the supplies are to be used. The quarry clerks upon ordering such material insert on the requisition the accounts to which the material is to be charged.

Coal, explosives, and gasoline are inventoried, and the quarry clerk reports at the end of each month the amount received during the month, the quantity used during the month, where used, and the balance on hand at the end of the month.

In addition, an inventory report is also sent to the main office showing tons of rock shot down during the month, tons of rock removed from quarry floor during month, tons of rock remaining on quarry floor, holes drilled and used during month, balance on hand at the end of the month, tons of stone placed in and taken out of storage during the month, and balance of crushed stone on hand at the end of the month. A stripping report is also rendered at the end of each month.

To insure regular deliveries of coal, a standing order is usually placed with the vendor to deliver a certain number of cars weekly. This order is changed from time to time according to the demands of the plant.

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COORDINATION OF OPERATIONS

Communication between the different departments is made by means of telephones which are conveniently placed in the quarry office, scale house, machine shop, and hotel. In cases of breakdowns in departments where there are no telephones, communication between departments is made by means of signals.

PER CENT EXTRACTION

The ratio of stone sold to stone broken from solid is about 98 per cent; 2 per cent is lost through washing. All of the stone is sold as crushed stone except in a few isolated cases when one and two man stone is sold.

EMPLOYEE PAY SYSTEM

All of the employees are paid on an hourly basis except well drillers, the superintendent, quarry clerks, and the night watchman. Well drillers are paid an hourly rate with a bonus of 25 cents per foot for all footage drilled in excess of 100 feet per month.

During the year 1929 this plant operated 283 days, averaging 55 hours per week and making a total of 223,240 man-hours. The average hourly wage was $0.54-3/4.

SAFETY METHODS

Definite steps toward the formation of a safety organization were first taken in 1926, when a safety committee was appointed. This committee consists of the superintendent, clerks, and foremen in charge of the various operations. Meetings are held monthly, at which time inspectors' reports are read and discussed, means of preventing accidents that happened during the previous month are considered and any changes or additions which might be made to improve the safety of conditions or machines about the plant are formulated. The company also employs a safety engineer who attends all of the meetings.

Early in 1928 the company started a safety competition among the three plants. The one having the best record each year has its name inscribed on a bronze plaque. The competition will continue for five years and at the end of this time the plant having its name on the trophy the greatest number of times will keep the trophy permanently.

The accident record of this plant since 1928 is as follows:

Year	Frequency Rate	Severity Rate	Man-hours
1928	87.59	18.70	219,417
1929	35.87	0.26	223,240
1930 (first 7 mos.)	7.82	0.04	127,809

ADMINISTRATIVE ORGANIZATION AT THE QUARRY

The superintendent is in complete charge of all operations and of appointing foremen to supervise the various departments. A foreman is placed in charge of each group as shown:

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		Number of men
1.	Stripping	2
	Well drilling	2
2.	Tunnel drilling	4
	Secondary drilling	10
	Loading to quarry cars	7
	Transporting to crusher	7
3.	Crushing and screening	8
4.	Main railroad	8
	Scale house	1
	Ground storage	2
	Browning crane	2
	Caterpillar shovel	2
5.	Power	2
	Air compression	1
6.	Machine shop	6
7.	Blacksmith shop	2
8.	Welding shop	4
9.	General plant administrative	3
	General yard	2
	Truck	1
	Hotel	1
	Dwellings	0
		78

About two years ago the foremen of the different departments organized a club, which they named the Progressive Club, for the purpose of meeting monthly to discuss the many problems which they encounter in their respective departments and to provide ways and means of reducing costs. These meetings are held on the men's time, the attendance not being compulsory. A new member is admitted to the club after his name has been presented by one of the members and approved by all. Members showing lack of interest through nonattendance are notified that they are no longer members. Three members have been admitted and none dropped since the organization of the club.

At each meeting every member is given an analysis of his departmental costs during the previous month, which shows a unit cost per hour, ton, or on whatever basis his department costs are figured, and is given an opportunity to question any item appearing thereon.

After the costs are discussed a mock trial is held, one member, whose name has been drawn by lot the previous month, is charged with doing things in and about the plant which may or may not be true. The idea is to give the members something to talk about, bringing things to their attention which they ordinarily would not see and at the same time to bring before each foreman the problems of the other foremen. To prevent the bringing up of charges

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of a personal nature, the charges are drawn up by the cost accountant, who together with superintendent, quarry clerk, and safety engineer attend all meetings.

ENGINEERING

The engineering staff, which consists of two engineers and two assistants, performs all of the engineering work for the three plants which are in operation and cares for all other property owned by the company.

Summary of costs at the Monocacy quarry, 1929

Total material loaded during 1929:

Overburden, 16,202 cubic yards dirt; Production stone, 441,915 short tons.

Name of account	1 Labor	2 Super-vision	3 Air Drills Steel	4 Power Cost	5 Fuel Cost	6 Explo-sives	7 Other Supplies	8 Total
Stripping (cu. yds.)								
Drilling	$.0960	$.0015	$.0080	-	$.0253	-	$.0022	$.1330
Blasting	-	-	-	-	-	-	-	-
Loading	.1665	.0025	-	-	0940	-	.0630	.3260
Transportation	.1564	.0024	-	-	.0316	-	.0198	.2102
	.4189	.0064	.0080	-	.1509	-	.0930	.6692
Stripping (Per ton stone prod.)								
Drilling	.0035	.0001	.0003	-	.0009	-	.0001	.0049
Loading	.0048	.0001	-	-	.0013	-	.0015	.0077
Transportation	.0068	.0001	-	-	.0032	-	.0018	.0119
Mining (Per ton stone prod.)								
Drilling (primary)	.0144	.0001	-	.0017	-	-	.0023	.0185
Do. (secondary)	.0101	.0022	.0006	.0163	-	-	.0002	0294
Blasting (primary)	.0002	-	-	-	-	.0208	-	.0210
Do. (secondary)	.0041	.0001	-	-	-	.0200	.0003	.0245
Loading	.0420	.0066	-	-	.0098	-	.0193	.0777
Transportation	.0218	.0034	-	-	.0072	-	.0061	.0385
Crushing (primary)	.0262	.0054	-	.0292	-	-	.0291	.0899
Do. (secondary)	.0145	.0032	-	.0162	-	-	.0162	.0501
Screening	.0043	.0017	-	.0048	-	-	.0039	.0147
Elevating	.0015	.0002	-	.0016	-	-	.0016	.0049
Conveying	.0017	.0003	-	.0019	-	-	.0019	.0058
Washing	-	-	-	-	-	-	.0007	.0007
Sand	.0048	.0008	-	.0027	-	-	.0020	.0103
Storage[1] (in)	.0257	.0037	-	-	.0150	-	.0070	.0514
Do. (out)	.0256	.0034	-	-	.0150	-	.0064	.0504
Miscellaneous plant	.0264	.0012	-	-	.0025	-	.0308	.0609
Total operating	.2384	.0326	.0009	.0744	.0549	.0408	.1312	.5732

[1]Storage includes transportation.

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Summary of costs in units of labor, power, and supplies, Monocacy quarry, 1929.

Material loaded during 1929:

Overburden, 16,202 cubic yards (weight per cu. yd. loose measure 2,000 lbs.)
Production, 441,915 short tons (weight per cu. yd. loose measure 2,700 lbs.)

	Stripping	Mining	Crushing	Other	Total
A. Labor:					
(Man-hours per ton stone)					
Drilling	-	.0384	-	-	.0384
Blasting	-	.0023	-	-	.0023
Loading	.0155	.0398	-	.0162	.0715
Haulage	.0072	.0308	-	.0330	.0710
Miscellaneous	-	.0368	.0883	.1323	.2574
Supervision	.0005	0254	.0150	.0237	.0646
Total Labor	.0232	1735	.1033	.2052	.5052
Average tons per man per shift	431	57.6	96.8	48.7	20
Labor, percentage of total cost	-	-	-	-	31.13
B. Power supplies:					
Explosives (lbs. per ton)		.3112	-	-	.3112
Total power (kw.h. per ton):					
1. Shovels		-	-	-	-
2. Locomotives		-	-	-	-
3. Air compression		.2420	-	.2160	.4580
4. Drills		.0317	-	-	.0317
5. Pumping		-	-	-	-
6. Crushing		-	1.7782	-	1.7782
7. Screening		-	.1880	-	.1880
8. Elevating		-	.0627	-	.0627
9. Conveying		-	.0744	-	.0744
10. Sand		-	.1029	-	.1029
11. Drying		-	-	-	-
12. Storage		-	-	-	-
13. Shops		-	-	.3211	.3211
14. Lighting		-	-	.0212	.0212
Fuel (tons of coal per ton)	.007	.035	-	.063	.105
Other supplies in percentage of total supplies and power		-	-	-	43.71
Supplies and power, percentage of total costs		-	-	-	39.46
C. Percentage of total cost		-	-	-	70.58

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Detailed average shovel costs, direct operation
Monocacy quarry, 1929
Osgood 29

Type of shovel, Caterpillar. Size of dipper, 1 yard.
Tons of overburden loaded, 8,101, cubic yards - 16,202.
Tons of stone uncovered, 441,915.
Tons of stone loaded, None.

	Amount	Waste Cost per ton	Stone Uncovered Cost per ton
Shovel operation:			
Engineer	$1,051.15	$.1298	$.0024
Fireman	875.95	.1081	.0020
Other operating labor	350.38	.0433	.0008
Total operating labor	2,277.48	.2811	.0052
Fuel	1,418.25	.1751	.0032
Grease and lubricants	32.33	.0040	.0001
Coal, crane expense	104.16	.0129	.0002
Other operating supplies	107.01	.0132	.0002
Total supplies	1,661.75	.2051	.0037
Shovel repair labor	420.23	.0519	.0010
Shop labor	281.96	.0348	.0006
Repair supplies	66.95	.0083	.0002
General overhauling	532.62	.0657	.0012
Total repairs	1,301.76	.1607	.0030
Total shovel operation	5,240.99	.6470	.0119
Drilling:			
Operating labor	1,401.53	.1730	.0032
Gas	410.47	.0507	.0009
Operating supplies	106.96	.0132	.0002
Repair labor	154.23	.0190	.0003
Repair supplies	57.43	.0071	.0001
Total drilling	2,130.62	.2630	.0048
Haulage:			
Locomotives	2,102.29	.2595	.0048
Cars	511.30	.0631	.0012
Track maintenance	431.22	.0532	.0010
Dump maintenance	322.11	.0398	.0006
Total haulage	3,366.92	.4156	.0076
General charges	103.46	.0128	.0002
Grand total	10,841.99	1.3384	.0245
Cost per ton, all material		1.3384	.0245

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Detailed average costs, direct operation

Monocacy quarry, 1929

Primary drilling, 1,420 feet - Well Drill

	Amount	Cost per ton
Primary drilling:		
Labor operating	$4,225.70	$.0096
Power	746.05	.0017
Labor repairs	2,073.26	.0047
Material repairs	157.55	.0004
Tools and Miscellaneous supplies etc.	386.21	.0009
Shops	477.16	.0010
Lubricants	28.12	.0001
Supervision	24.30	.0001
	8,118.35	.0185
Primary blasting:		
Labor operating	81.38	.0002
Explosives	9,191.83	.0208
	9,283.21	.0210
Summary:		
Total stripping costs	10,841.99	.0245
Total drilling primary costs	8,118.35	.0185
Total blasting primary costs	9,283.21	.0210
Total cost rock on quarry floor	28,243.55	.0640
Secondary drilling:		
Labor operating	4,108.14	.0093
Air	7,199.45	.0163
Operating supplies	90.38	.0002
Repair labor	361.44	.0008
Supervision	972.21	.0022
Repair supplies	254.21	.0006
	12,985.83	.0294
Secondary blasting:		
Labor operating	1,808.13	.0041
Explosives	8,852.57	.0200
Supervision	44.19	.0001
Other supplies	145.46	.0003
	10,850.35	.0245

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Detailed average costs - direct operation

Monocacy quarry, 1929

Marion Osgood 120

Bucyrus 95C

Type of shovels, steam railway. Size of dippers, 4 yards.

Tons of stone loaded, 441,915 tons.

	Amount	Cost per ton
Engineers	$3,394.43	$.0077
Cranemen	2,588.26	.0059
Firemen	2,144.17	.0049
Pitmen	783.53	.0018
Total operating labor, etc.	8,910.39	.0203
Fuel	3,695.04	.0083
Grease and lubricants	73.84	.0002
Coal crane expense	649.83	.0015
Other operating supplies	260.26	.0006
	4,678.97	.0106
Shovel repair labor	4,725.07	.0107
Shops	1,185.97	.0026
Repair supplies	2,880.11	.0065
General overhauling	4,121.04	.0093
Supervision	2,916.64	.0066
	15,828.83	.0357
Total shovel operations	29,418.19	.0666
Labor other than shovel	4,904.65	.0111
Secondary drilling:		
Labor operating	4,108.14	.0093
Air	7,199.45	.0163
Operating supplies	90.38	.0002
Repair labor	361.44	.0008
Supervisor	972.21	.0022
Repair supplies	254.21	.0006
	12,985.83	.0294
Secondary blasting:		
Labor	1,808.13	.0041
Explosives	8,852.57	.0200
Supervision	44.19	.0001
Other supplies	145.46	.0003
	10,850.35	.0245

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Detailed average costs, direct operation
Monocacy quarry, 1929

	Amount	Cost per ton
Haulage to crusher:		
Labor operating	$4,235.06	$.0096
Fuel	2,842.97	.0064
Labor repairs - roll stock	3,214.15	.0073
Material repairs - roll stock	936.73	.0021
Labor maintenance of way	2,177.68	.0049
Material maintenance of way	407.65	.0009
Miscellaneous supplies	411.26	.0009
Lubricants	89.39	.0002
Shop repairs	883.08	.0020
Supervisor	1,502.51	.0034
Coal crane expense	357.01	.0008
	17,057.49	.0385
Crushing, washing, and screening:		
Labor operating	8,015.05	.0180
Power	23,769.50	.0537
Labor repairs	13,340.76	.0302
Material repairs	16,723.38	.0378
Tools and miscellaneous supplies	1,392.24	.0031
Lubricants	1,811.85	.0041
Water rights	300.00	.0007
Shops	3,404.78	.0077
Supervision	4,772.68	.0108
	73,530.24	.1661
Sand storage:		
Labor operating	979.75	.0022
Power	1,193.87	.0027
Labor repairs	1,158.97	.0026
Material repairs	304.50	.0007
Tools and miscellaneous supplies	204.23	.0005
Shops	365.76	.0008
Supervision	366.01	.0008
	4,573.09	.0103

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Detailed average costs, direct operation
Monocacy quarry, 1929

Shipments, 426,725 tons.

	Amount	Cost per ton
Railroad - direct shipments:		
or ground storage:		
Labor operating	$4,383.93	$.0103
Fuel	6,248.65	.0146
Labor repairs - roll stock	3,598.06	.0084
Material repairs - roll stock	246.28	.0006
Labor maintenance of way	1,670.91	.0039
Material maintenance of way	236.91	.0006
Tools and miscellaneous supplies	247.25	.0007
Lubricants	105.53	.0002
Shops	1,107.08	.0026
Crane expense, coal	128.80	.0003
Supervision	1,450.87	.0034
	19,424.27	.0456
Scale house:		
Labor operating	6,792.07	.0159
Labor repairs	123.60	.0003
Material repairs	2.39	
Miscellaneous supplies	241.41	.0006
	7,159.47	.0168
Ground storage:		
Labor other than 16-foot crane	2,653.53	.0062
16-foot gage crane		
Labor operating	1,609.97	.0038
Fuel	2,324.34	.0054
Labor repairs	1,074.20	.0025
Material repairs	596.34	.0014
Tools and miscellaneous supplies	2,070.83	.0049
Lubricants	93.52	.0002
Shops	449.19	.0011
Supervision	1,578.88	.0037
	9,797.27	.0230
Browning locomotive crane (service)	4,507.53	.0102
Total shipping expense	43,542.07	.1018

Tons moved in ground storage	318,460
Tons moved out ground storage	294,499
Total tons moved	612,959

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Summary of detailed average costs - direct operation
Monocacy quarry, 1929

	Amount	Cost per ton
Stripping costs	$10,841.99	$.0245
Primary drilling	8,118.35	.0185
Primary blasting	9,283.21	.0210
Total cost of rock on quarry floor	28,243.55	.0640
Secondary drilling and blasting	23,836.18	.0539
Loading to crusher	34,322.84	.0777
Hauling to crusher	17,057.49	.0385
Crushing washing and screening	73,530.24	.1661
Sand	4,573.09	.0103
Miscellaneous plant	26,912.62	.0609
Total cost at crusher	208,476.01	.4714
Shipping Expense:		
Railroad, direct or storage	19,424.27	.0456
Scale house	7,159.47	.0168
Ground storage	16,958.33	.0394
Total shipping expense	43,542.07	.1018
Total operating costs	252,018.08	.5732

Note: Cost per ton units are based on production (441,915 tons) up to and including "total cost at crusher." Cost per ton units are based on shipments (426,725 tons) including "total shipping expense."

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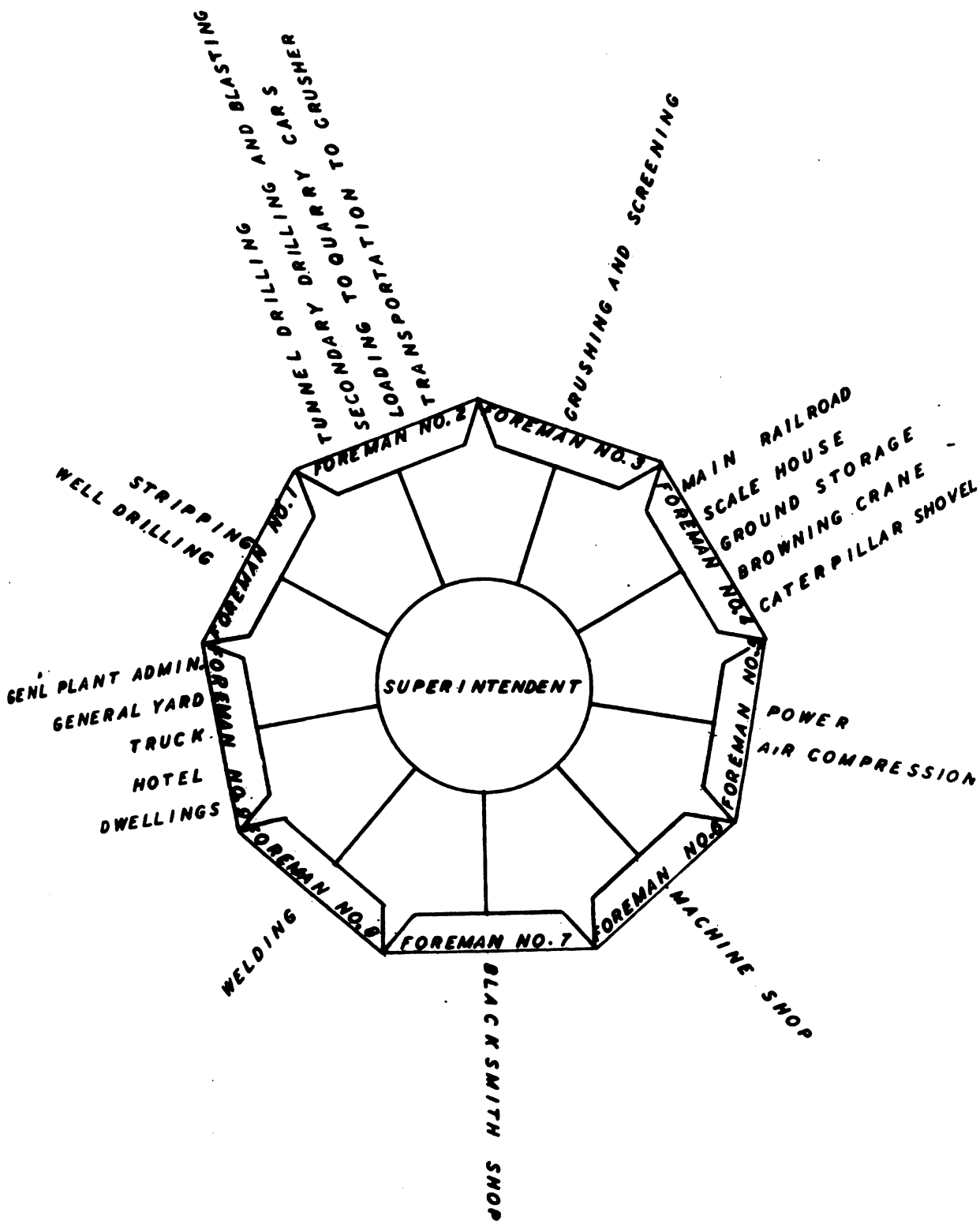

Figure 12.- Quarry organization chart

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